Functional Requirement Specification

Project X Low Energy Beam Transport Chopping System

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Revision History

Revision	Date	Section No.	Revision Description
0	1/30/13	All	Initial Release.

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1. Introduction:

The purpose of this document is to define the specifications for the PXIE Low Energy Beam Transport (LEBT) chopper. LEBT beam is comprised of 30 keV H^- ions. The ion source supplies up to 10mA and nominally 5mA of DC beam to the LEBT. Upstream components of the LEBT steer and focus the beam into the chopper [1]. Since the ion source cannot be pulsed effectively, the chopper is the means of providing pulsed beam to the PXIE RFQ for commissioning and testing purposes. The chopper will also act as a virtual beam stop for machine protection.

2. Scope:

The LEBT chopper design scope includes the vacuum vessel that contains the actual kicker and absorber. The kicker uses an electric and/or magnetic pulse to steer beam into the absorber when beam is not desired in the RFQ. The design scope includes the structural, electrical, and thermal properties of the kicker, and the structural and thermal properties of the absorber. It includes all power supplies and local controls necessary to drive the kicker, and all components and local controls required to maintain vacuum. It also includes any components necessary to protect the chopper system from beam damage. This may include cooling systems, parasitic instrumentation, and/or upstream aperture limitations.

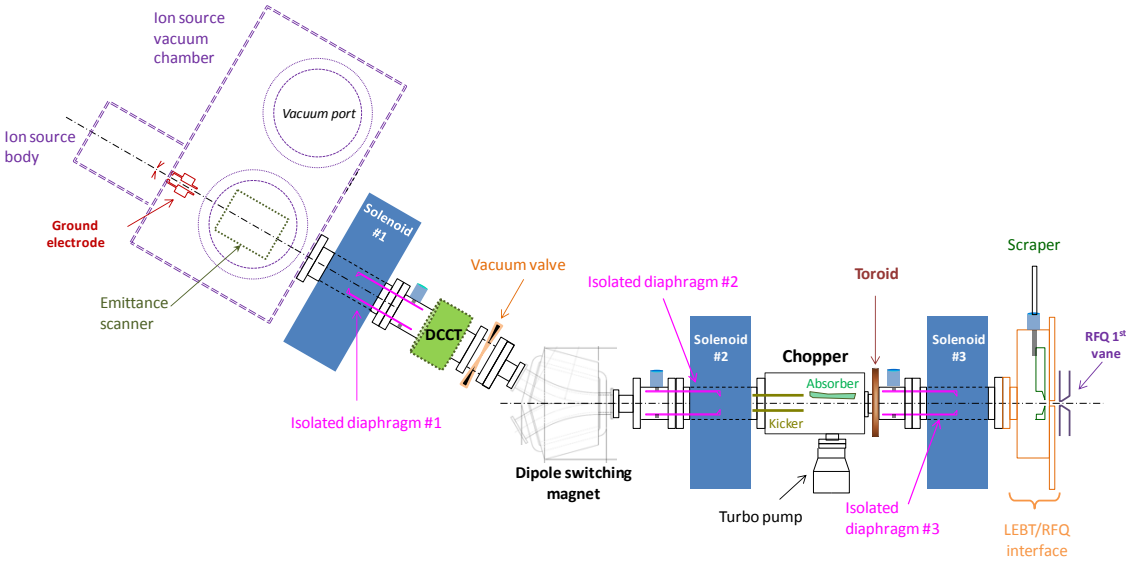

Figure 1: Proposed ion source and LEBT beam line layout. The chopper is located between Solenoids #2 and #3.

3. Interfaces & Key Assumptions:

a. Interfaces:

The chopper system must interface with other systems outside the scope of the chopper system design. Final technical specifications for the chopper system will incorporate agreement on interfaces between the other systems. The list below with Figure 2 describes the system interfaces:

- Mechanical placement and connection to LEBT beam line
- Input and output beam parameters (kicker on and off)
- Timing and triggering system
- Machine protection system
- Communication and control system
- Data acquisition system (for diagnostics)
- Beam line enclosure layout
- Cooling water system (if necessary)

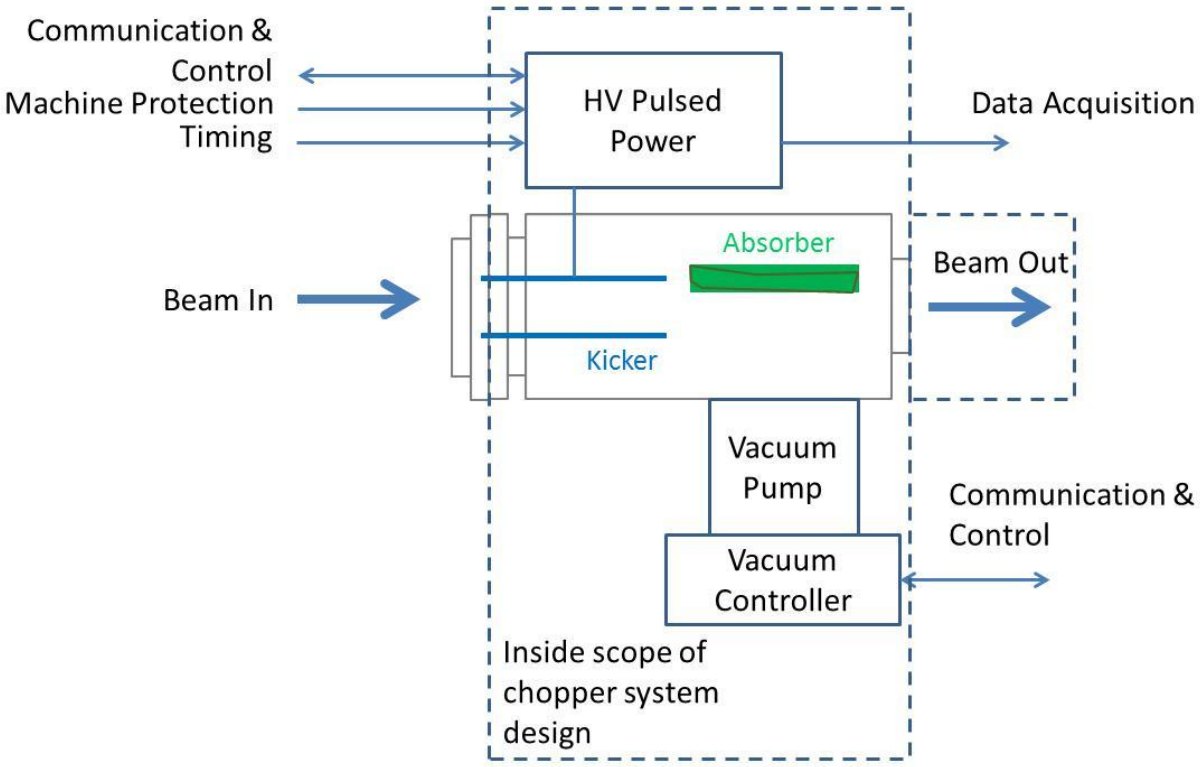

Figure 2: Conceptual block diagram of chopper system and system interfaces. Items within the dashed boxes are part of chopper system scope.

b. Modes of Operation:

The chopper is designed for three modes of operation. The first mode is as the first responder to the Machine Protection System (MPS). In this mode, the kicker drives the entire LEBT beam into the absorber to protect downstream beamline components from beam damage. A second, slower layer of the MPS will turn off the ion source.

The second mode of operation is a beam pulse width and duty factor controller. This mode is used to commission downstream beamline components with low duty factor

beam. A possible application of this mode is for ion clearing in MEBT, when the output beam is interrupted for ~1μs with ~1 kHz repetition.

In the third mode of operation, the chopper voltage is off, which allows DC beam to pass through the LEBT to the RFQ.

4. Constraints & Requirements

The following table summarizes the constraints and requirements for the chopper system, derived from the PXIE LEBT FRS.

Table 1. Summary of Chopper Constraints & Requirements

Beam Input		
	Maximum Beam Current	10 mA
	Beam Energy	30 kV
Extinction*		
	Extinction Ratio (for beam at nominal width)	$< 10^{-4}$
	Pass-Thru Loss (for beam at nominal width)	< 5%
Pulse Operation		
	Maximum Pulse Width	DC
	Maximum Rise/Fall Time (10%-90% beam downstream)	100ns
	Minimum Flattop Pulse Width	150ns
	Maximum Pulse Frequency	1MHz
Machine Protection		
	Maximum Pulse Latency	1μs
Vacuum		
	Maximum Vacuum Pressure	~ 10^{-6} torr
Mechanical		
	Maximum Length (flange to flange)	23cm

* For estimation of losses and extinction, the beam entering the lens upstream of the chopping system is assumed to be Gaussian and un-neutralized.

a. Safety:

The chopper design will conform to all laboratory ES&H standards [3]. There will be no exposed, high voltage terminals. The high voltage power supply will have a single, interruptible power line, or a specific LOTO procedure will be written.

b. Documentation & Review:

The following documents will be generated prior to completion of the design in accordance with the policies defined in the Fermilab Engineering Manual [4]:

- Design Specifications
- Engineering Risk Assessment
- Engineering Drawings

- Hazard Analysis & Necessary Safety Procedures
- Operation Manual

In addition, the design will be reviewed by a team of engineers with experience in high voltage kickers to analyze cost efficiency and safety. The final design will also be reviewed by an accelerator safety committee examining issues associated with beam line components.

c. Testing and Commissioning:

The chopper system requirements will be tested in the LEBT beam line prior to RFQ installation. A calibrated beam toroid will be installed just downstream of the chopper, and the signal levels will be compared to the DCCT that measures the output current of the ion source (see Figure 1).

5. References:

Documents with reference numbers listed are in the Project X DocDB:
http://projectx-docdb.fnal.gov

[1] PXIE LEBT Functional Requirements Specification
Document #: Project-X-doc-912

[2] PXIE MEBT Functional Requirements Specification
Document #: Project-X-doc-938

[3] Fermilab ES&H Manual
http://www-esh.fnal.gov/pls/default/esh_home_page.page?this_page=15053

[4] Fermilab Engineering Manual
http://www.fnal.gov/directorate/documents/FNAL_Engineering_Manual_REVISED_070810.pdf